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The Research on Intelligent Monitoring Technology of NC Machining Process

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Abstract

According to the current situation and problems of CNC machine tool monitoring technology, we discuss the intelligent monitoring technology development and CPS features, and propose a four-layer architecture CPS NC machining process intelligent platform which realizes the real-time monitoring and three-dimensional display of machine tools. And we discuss the system composition and realization of the developing platform.

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*Keywords:*CNC Machine; NC Machining Process; Cyber-physical System; Intelligent Monitoring Technology;

1. Introduction

Along with the development of digital control technology, high-performance drive technology and sensor technology, the CNC machine tools becomes much more powerful and has been widely used in manufacturing industry. Network, automation, high-precision, high efficiency is the main direction of the current development of CNC machine tools, With the improvement of the function and performance of CNC machine tools, the demand of remote data acquisition and condition monitoring of CNC machine tools turns to be urgent. In this context, various types of CNC machine tool monitoring technology have been greatly developed.

2. Overview of the monitoring technology of NC machine tools

Based on the NC machine tool monitoring network, it is easy to achieve automated data acquisition and condition monitoring. Equipment operation status can be displayed through the monitoring interface, the failure will be easily get at the first time and passed to relevant technical personnel. At the same time, such one-hand state information and fault information makes it possible for production personnel, technical personnel and equipment maintenance personnel to achieve remote fault diagnosis, job scheduling and resource allocation. Through on NC machine network monitoring and diagnosis, it changes the passive situation of the diagnosis personnel constantly on the run of equipment malfunction. The development of the global computer network and sensor technology used on NC machining process provides a solid technical foundation [1].

Generally, most of the monitoring systems are expandable, and the system consists of collecting layer, processing layer, service layer and application layer. The structure is shown as Fig. 1.

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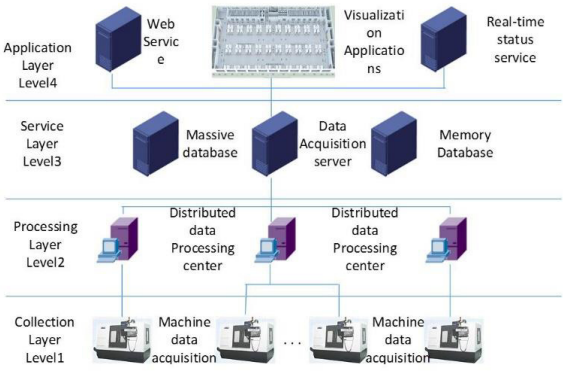

Fig. 1. CNC Machine Data Acquisition System Architecture

Problems existing in the monitoring technology of NC machine process:

1) Low real-time and poor reliability.

Due to the limitation of current technology, the process is affected by the performance of data acquisition, transmission network reliability, bandwidth and transmission delay of sampling frequency, it is difficult to achieve higher real-time performance.

2) The function of data acquisition system is single, and parameters are few.

At present, the data acquisition solution is usually based on the hardware board, and in consideration of different NC systems, the functional plan has to be abstract, which makes acquisition function single and parameters relatively limited.

3) The lack of real-time reiteration of intuitive and efficient processing state

To realize the collection of state data of NC machine tool, is only the first step of the whole process, how to establish an efficient and intuitive visual monitoring interface is a difficulty in the design and implementation of the system. To monitor the specific NC machine tool, it usually lacks of effective means of reproduction. The system is generally based on a custom development data window, and it is difficult to visualize the display process condition.

4) The monitoring system is mainly based on one-way data acquisition. It lacks of adequate two-way control ability.

At present, NC machine data acquisition mainly concentrates on unidirectional data acquisition, it lacks of controlling ability. But with the improvement of machine intelligence, we not only need to achieve real-time acquisition of NC machine status information, but also need to evaluate and respond to the running state of NC machine tools at the same time, meanwhile, we also need to send out the control commands and achieve controlling the machine tools, which put forwards new challenges to the monitor system of the NC machine tools.

3. Intelligent monitoring technology and CPS

With the development of computing, control, and information technology, the concept of Cyber-Physical System (CPS) emerges as the times require. Raj Kumar says, start for now on, it will be the era of CPS, through embedding computing intelligence, communication and control capabilities, as well as using new sensors and actuators into physical system. It will greatly enhance the adaptive capacity, automation, efficiency, reliability, security and availability in industrial control system, intelligent transportation and other national or even world-class application. NSF research report pointed out that the development of CPS has begun to significantly change our life, applications of CPS in intelligent medical, smart grid, intelligent vehicle, and intelligent transportation field enable us to get more sensitive, accurate and efficient service. At the same time, technical CPS intelligent device has been used in some environment which is not suitable for human participation, such as earthquake rescue, fire and exploration.

3.1 About CPS

Baheti says, CPS system is a combination of all kinds of computing elements and physical elements, it is a highly reliable system which is coordinated under the action of dynamic uncertain events. Lee considers, CPS is the integration and interaction of computing process and physical process, that is, through the embedded computer and network to realize the monitoring and control of physical processes. Raj Kumar believes, CPS is achieved by computing and communication kernel to achieve the detection, coordination, control and integration of physical engineering system.

JiFeng He, an academician of Chinese Academy of Sciences, thinks that, CPS is a controllable and physical equipment system based on Environment perception and integration of computing, communication and control capabilities. Zhongjie Wang, a professor of TONGJI University, gives his definition that, CPS emphasizes the interaction of Cyber-physical, it involves the integration of massive heterogeneous data in the future network and the real-time processing and communication of uncertain information signals, the coordination and adaptive control of dynamic resources and capabilities. It is the next generation intelligent system with a high degree of autonomous perception, autonomous judgment, autonomous regulation, and self-control, and is able to realize the virtual world and the real physical world.

3.2 Characteristics of CPS

CPS consists of computing equipment network equipment and physical equipment, all devices cooperate with each other to determine their unique features and characteristics. ShaoLun Xu summarizes the characteristics of the information fusion system and thinks the main features of CPS are as follows:

1)Complexity and heterogeneity: CPS is composed of multiple heterogeneous communication network, computing system, control system, and physical equipment, through the mutual integration, the physical equipment has five functions: computing communications, precise control, remote coordination and autonomy, it is a multi-dimensional open system, with a high degree of complexity, and the heterogeneity is also very obvious.

2) Fusion: CPS achieves the depth of integration through the calculation process and the physical process of the interaction between the feedback loops. This leads to the change from the number of objects into analog, from discrete to continuous, from static to dynamic, it is a system of the coexistence of a variety of types of computing objects.

3) Autonomy and intelligence: While CPS in the integration of computing, control and physical processes, it shows strong autonomous skills and intelligent decision ability, which makes the calculation more flexible and intelligently collaborated between components and the physical environment. Mainly embodied in the self-organization and self-Management.

4) Real time and mass: CPS needs timely understanding of the status of the physical device, however, the involvement of mobile devices will result in random changes in the state from equipment, therefore, it is necessary to carry on the real time reorganization to the physical equipment, which is very high to the time determinism and the parallelism of the computation process, and also to the request of the real-time nature of the network.

3.3 The architecture of intelligent monitoring CPS

In general, the basic physical components of CPS include a sensing unit, an execution unit, and a decision control unit. Sensing unit is a kind of embedded device which can monitor the external signal, physical condition and chemical composition in real time; The execution unit is an embedded device which can receive the control instruction and control the controlled object; Decision control unit is a kind of logic control device which can generate control logic according to user's definition; Combined with the feedback loop control principle, the basic physical components constitute the logic unit of the most basic monitoring and control functions of CPS. As shown in Fig. 2. Below.

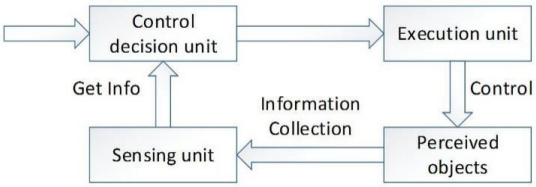

Fig. 2.Basic physical composition of CPS

To realize the integration of CPS information system and physical system, we first need to abstract all kinds of physical entities in the information system. Researchers both at home and abroad have put forward different abstraction strategies. For example, in literature [10], the CPS is abstracted into three layers of structure, the environment layer, the service layer and the control layer, from the point of solving the limited computing resources of embedded equipment. Fig. 3. Is based on the system view of the CPS architecture.

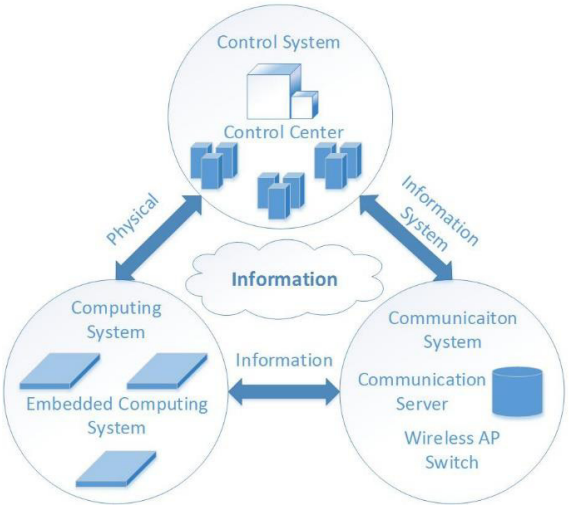

Fig. 3. CPS architecture based on system view

CPS nodes and the physical world interacts in real time, CPS obtains the change of the physical world in real time through the sensor unit, the information is delivered to the information processing unit or transmitted to other nodes by the communication unit. And communication unit receives the data and turns to the information processing unit, information processing unit will process and fuse the information, and makes decisions based on the built in algorithm, and pass the results to the actuator unit or send to other nodes through the communication unit to realize the influence and control of the physical process. The method has a strong guiding role in the research of CPS, and the combination of service oriented architecture and the design and development of CPS system.

4. An Intelligent Monitoring CPS of NC Machining Process

4.1 The hierarchy of Intelligent monitoring CPS of NC machining process

4.1.1 Definition of intelligent monitoring CPS of NC machining process

Intelligent monitoring CPS of NC machining process is an intelligent monitoring system that used for the actual production monitoring of CNC machine, Base on the Model building of 3D motion control features, the real-time state monitoring of NC machining process, the real-time data processing and analyzing, integrated with NC machining process 3D real-time recurrent, intelligent data analyzing, real-time machining state evaluation, machining error probe and warning and adaptive control capacity, connect with the high performance network. Its main features include: higher

calculating performance, higher dynamic behavior of process, higher accuracy of controlling, higher intelligence of operation and highly autonomy.

4.1.2 The hierarchy of Intelligent monitoring CPS of NC machining process

Reference to the 4-layer abstract structure of CPS based on SOA, this article brings a SOA based intelligent monitoring CPS of NC machining process, as shown in Fig. 4.

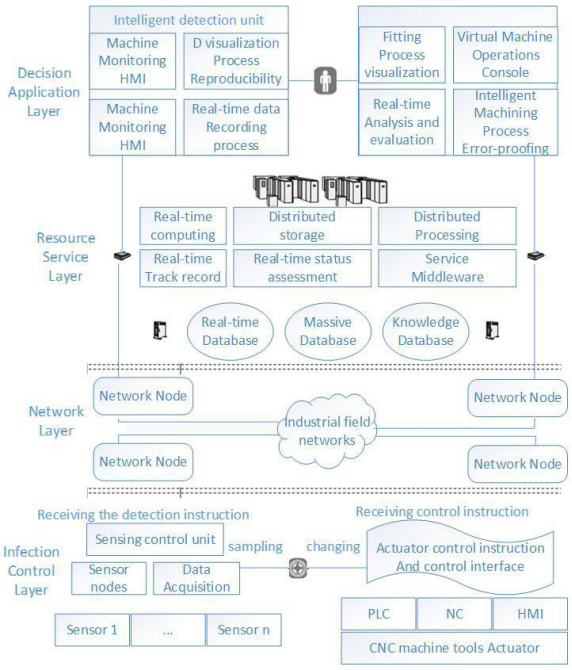

Fig. 4. System architecture of intelligent monitoring CPS of NC machining process

The composition of intelligent monitoring CPS of NC machining process

1）The sensor and controller layer

The Sensor and Controller layer of intelligent monitoring CPS is an interconnection point of cyber space and the actual physical CNC machine. This layer includes some physical elements, such as machine body, movement components, sensors, controllers, drivers, motors, and NC machining objects and fixtures, tools. Control technology, embedding system, sensing technology and communication technology are involved.

2) The network and communication layer

In the actual NC machining monitoring CPS, the biggest challenge of Network and communication layer is how to keep the ability high reliability, low time relay of transferring of large volume, real-time data between cyber space and physical space. Considering the actual transferring reliability and performance of field networks, it is necessary to use redundancy transferring network and use distributed data collecting strategy, and optimize the data collecting and processing methods between the sensing layer and the resource layer. The main goal of the optimization is to reduce the real-time data scale, data transferring time, and their network bandwidth requirement.

3) The resource and service layer

The resource and service layer is the core support platform of NC machining monitoring CPS. To the higher layer, this layer provides several services, such as data analyzing, graphic calculation, big data processing etc., and to lower layer, it provides support for massive data storage, processing. In the meantime, this layer will build a cyber space by abstraction of all virtual model for physical objects in the sensor and controller layer, provides service middleware for the communication between cyber space and physical space. In these terms, it is possible to send commands and receive states data between this layer and the lower physical layer.

4) The decision and application layer

The layer is aimed for application or the operators, its main goal is to realize the visualization of machining process, the automatic and autonomous monitoring and adaptive controlling of the actual machining process. As a highly autonomous intelligent monitoring CPS, massive data application, smart data analyzing is embedded in this layer. For the actual machining process, it can evaluate the real-time state of the process, forecast the coming machining states and remain process time, post alarm or fix error before error really happen.

4.2 System realization

Based on the four-layer architecture of intelligent monitoring CPS of NC machining process, we provide a platform which includes all the models of CNC machine movement components, such as spindles, axes, workbench and their dynamic movement relationship. And also it realizes the dynamic loading and interaction control of CNC machine model and all the movement components through the Real time data collected from the machine tool. The machine tool model and real time data are fused and displayed simultaneously in the virtual 3D scene as the Fig. 5. Below.

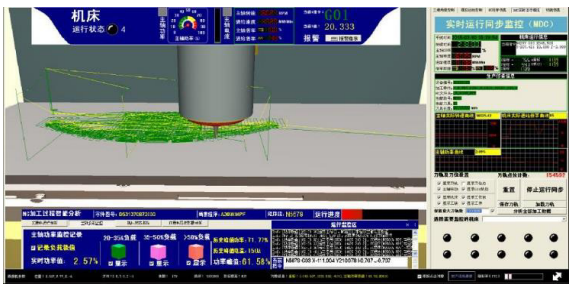

Fig. 5. System running interface.

On the basis of the closed loop control theory: “sense – analyze– decide – control –feedback - evaluate”, the platform realizes a more precisely prediction of machining load with an integrated massive data real-time processing and analyzing technology, the other key characteristics of the system includes: the intelligent recognition of error and abnormal

machining state, automatic alarm reporting, remote feed rate control and emergency stop etc. extracts faults and errors intelligently, combines with the error situation response rule and process methods, we believe this is an important basis for the finally realization of fully intelligent NC machining process.

5. Conclusions

The Intelligent monitoring platform greatly ensures the intelligent condition monitoring and fault diagnosis of the safety of work piece in CNC machining process and equipment. It improves the NC machining process monitoring technology level and the ability of fault diagnosis, solves the existing problem in NC machining process, and improves the production efficiency of machine. And this what we are thinking and doing to improve the NC machining process monitoring technology level and the ability of fault diagnosis, solve the existing problem in NC machining process, improve the production efficiency of machine.

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